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(54) Apparatus for performing surgical operations

(57) In apparatus for performing surgical operations, microwaves are radiated to bio-tissue from a monopolar needle electrode 9 in contact with the tissue and attached to a coaxial cable 8, and an operation of coagulation, haemostasis or transection is performed on the bio-tissue by means of thermal energy generated by the reaction of the microwaves on the bio-tissue. The bio-tissue can be operated upon in an easy, safe and bloodless manner and the apparatus can therefore be used for an operation on a parenchymatous organ having a large blood content for for coagulation or transection of a parenchymatous tumour.

A normally-open hand switch 10 and a normally-closed foot switch 11 control a power supply 2 energising a microwave generator 3 having controls 4, 5 to limit the output power and operating time.

When an operation has been completed, the electrode 9 is released from sticking to the tissue by energising a source 12 to pass a D.C. current between the electrode 9 and either an electrode 13 contacting tissue adjacent the operation area, or a metal shield member (21, Fig. 2, not shown) located on the operating hand piece adjacent the needle electrode and also connected to the outer conductor of the coaxial cable.

An endoscope may have a retractable microwave-radiating electrode (Figs. 3, 4, not shown).

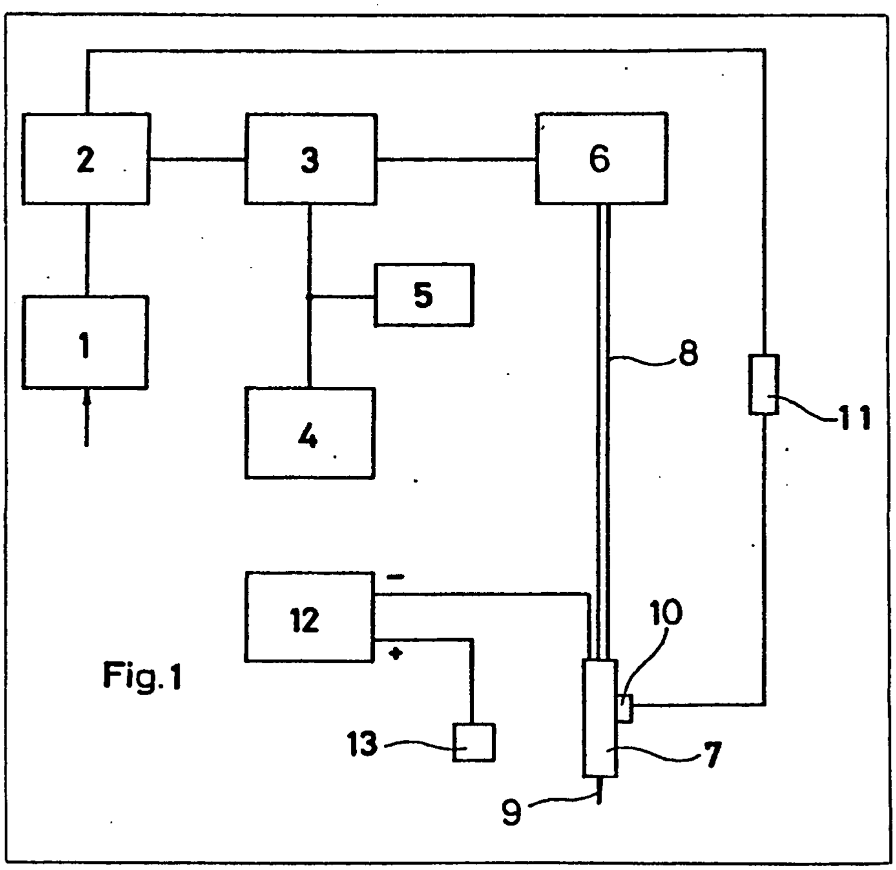

Fig.1

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Fig.1

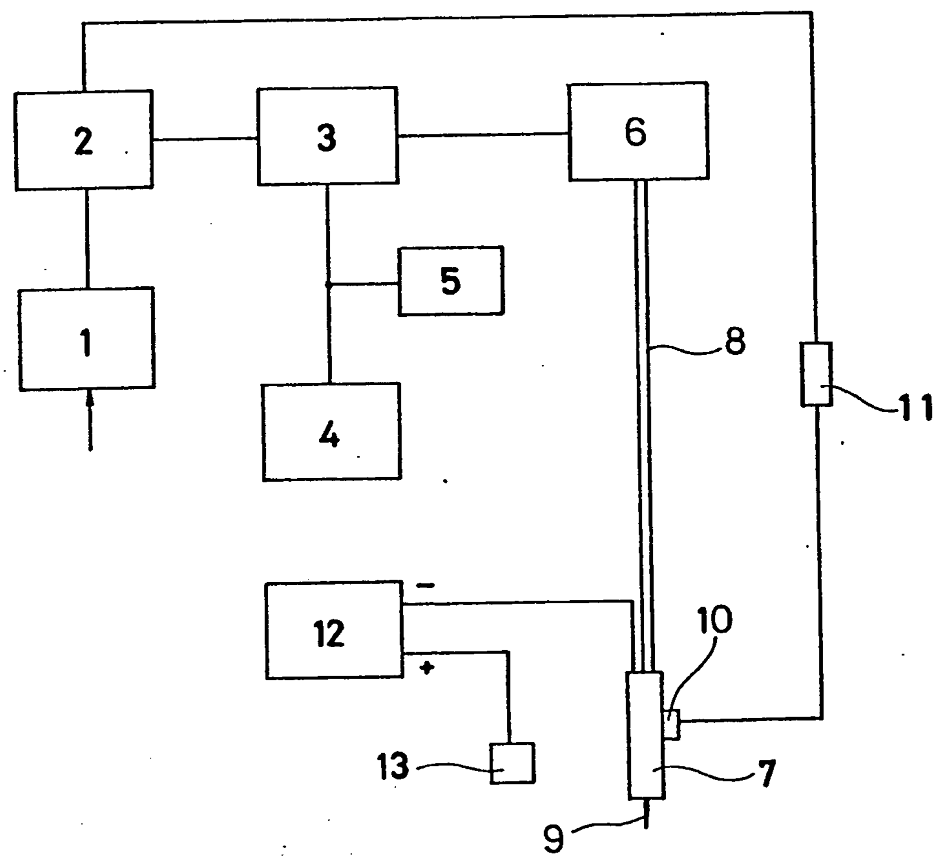


Fig. 2

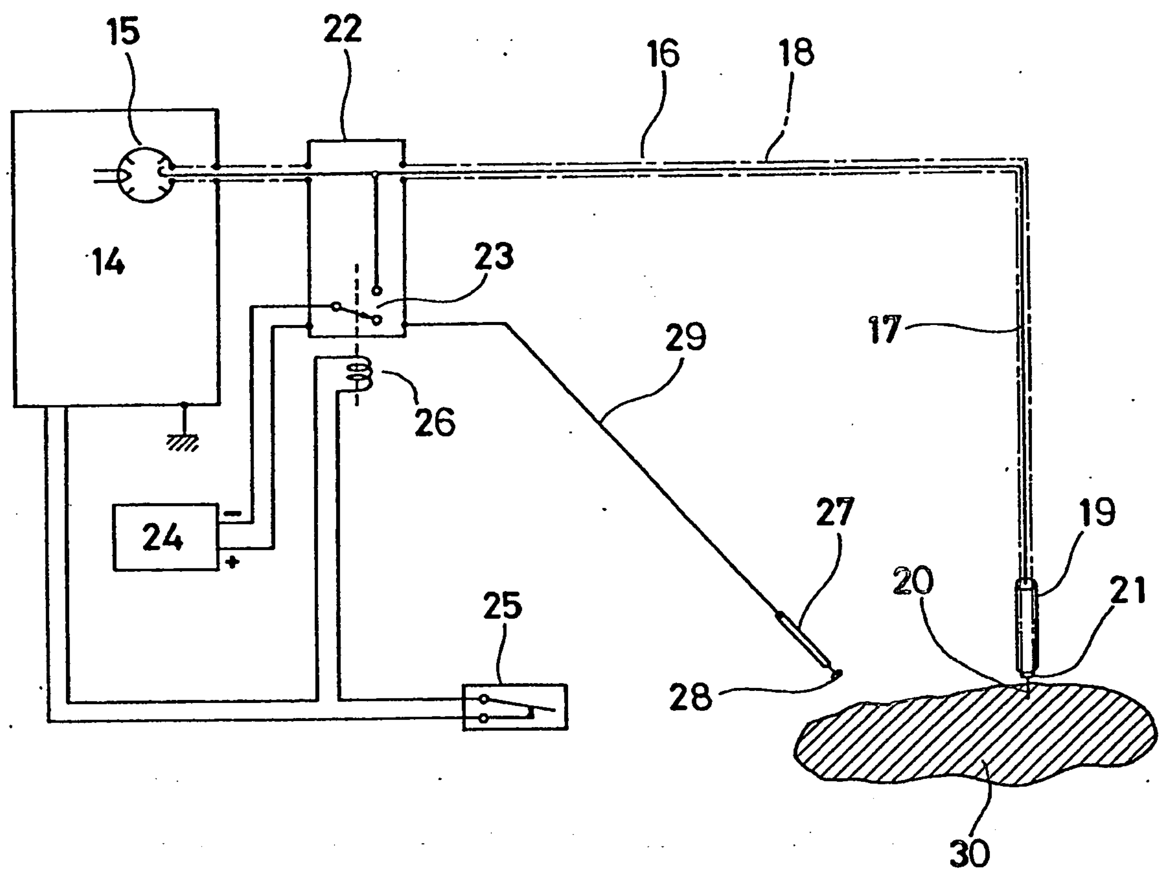


Fig.3

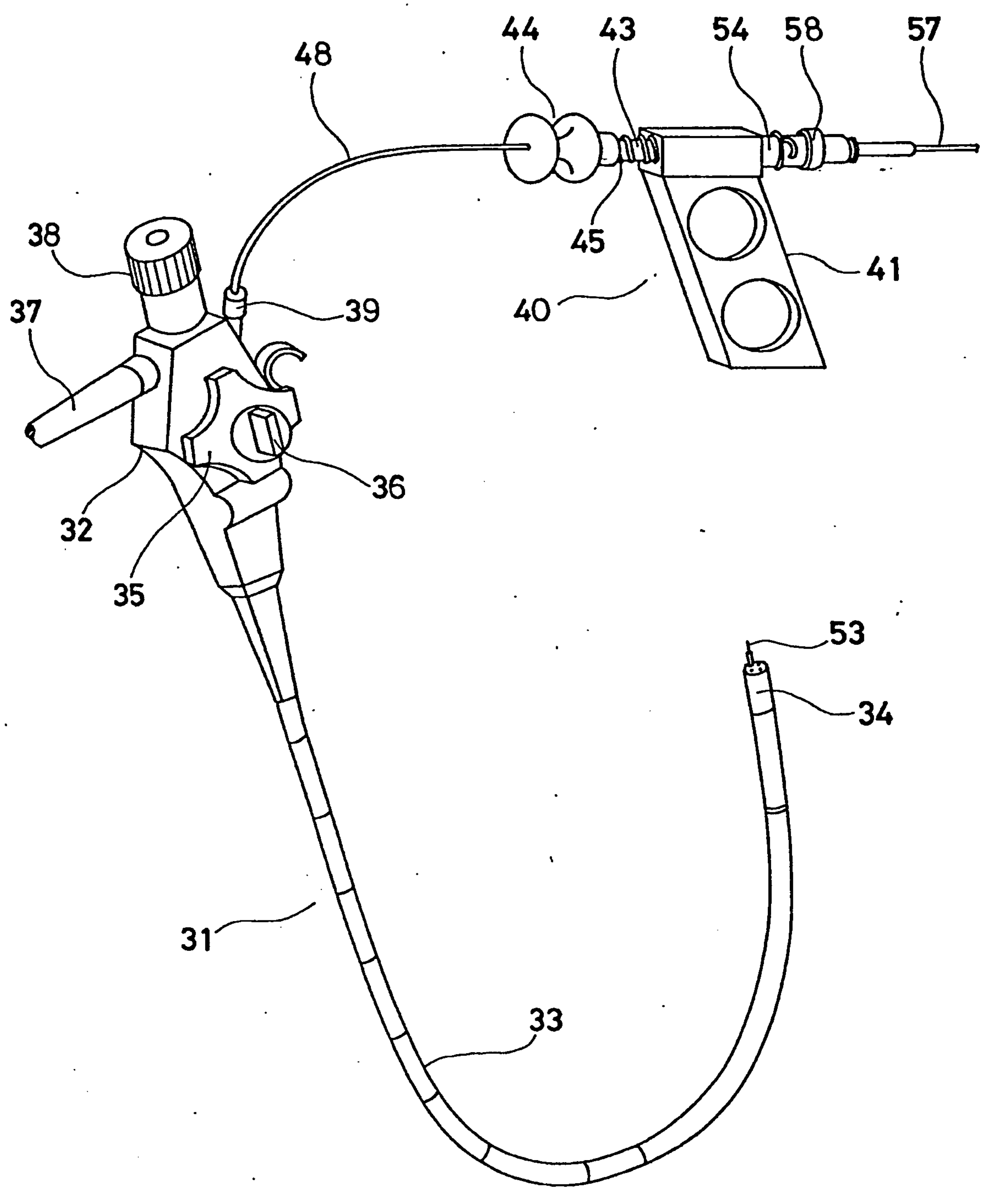
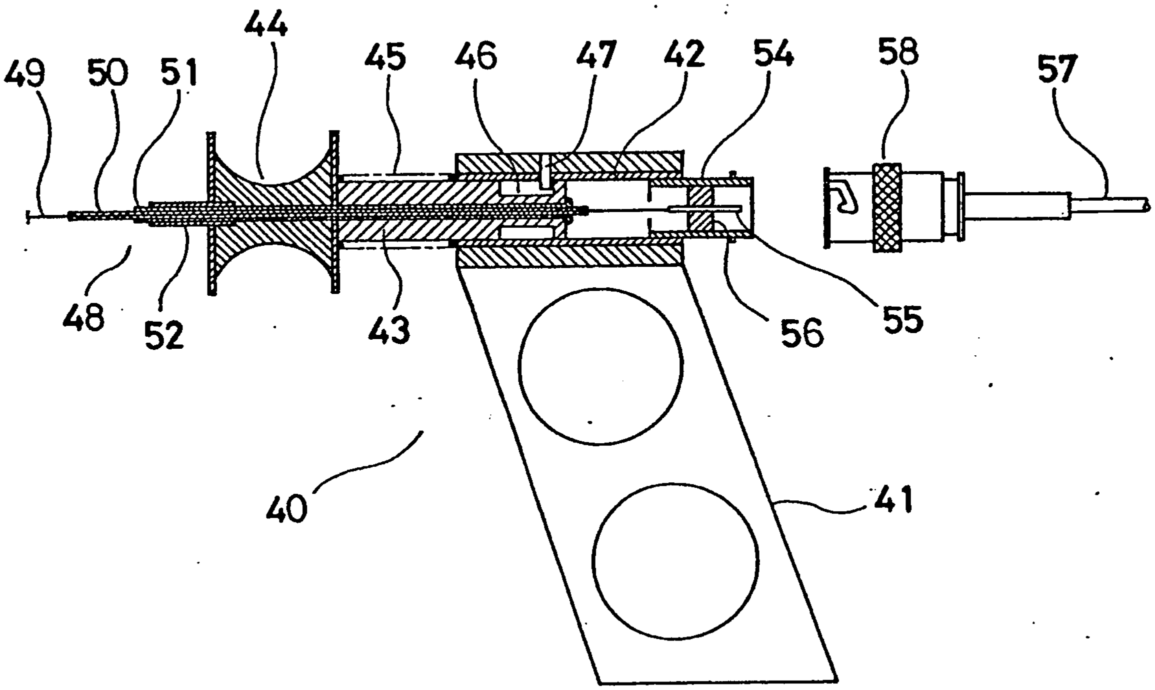


Fig. 4



SPECIFICATION

Apparatus for performing surgical operations

The present invention relates to apparatus for performing surgical operations.

Known devices for carrying out surgical operations include the electrocautery (high frequency knife) and laser operation device (laser knife).

The electrocautery uses a power supply having a frequency of 0.3 to 10 MHz, a wavelength of 1000 to 30 m and an ouput of 200 to 500 W, and includes a high frequency operating electrode of knife or tweezers type and a non-active electrode. With the non-active electrode mounted to another part of the patient's body, a high frequency current is caused to flow from the operating electrode to the non-active electrode so that haemostasis or coagulation is performed by cauterising the tissue by means of a high frequency spark discharge. Accordingly, there is often a risk of the patient getting burnt. Moreover, the tissue is degenerated by carbonisation and the degenerated tissue comes off with the passage of time, thereby causing rehaemorrhage which is, of course, very dangerous. Therefore, such an electrocautery is not suitable for operations on parenchymatous organs having a large blood content.

Moreover, in clinical practice, there is a danger of the patent being injured or receiving an electric shock. Also, at the stump, secondary haemorrhage after operation and cholerrhagia after operation are observed.

The laser operation device uses a power supply having a wavelength of 10.6 microns and an output of 50 to 100 W, and includes a hand-piece of condensing lens type. Therefore, the focus of the laser beams should be adjusted on the occasion of each operation. If the period of time of the radiation is improperly set, the laser beams become too strong. Accordingly, there is a danger of other tissue readily being damaged.

Moreover, if there is a light error in setting the angle of the arm for transmitting the laser beams, the optical axis is erroneously set and the beams subsequently radiate in unexpected directions. It is further to be noted that the range of movement of the arm is limited to a predetermined range in view of the laser optical axis.

Since, in performing haemostasis or coagulation, the laser operation device utilises thermal energy generated by the laser beams, the tissue is not degenerated by carbonisation. However, the maximal diameter of vessels which can possible be subjected to haemostasis is as small as 1.5 mm. Therefore, when blood vessels have diameter of 1.5 mm or more, it is disadvantageously necessary to ligate them before they can be amputated. Accordingly, the laser operation device is not suitable for emergency operations.

Moreover, the maximal diameter of the intrahepatic bile duct which can possible be closed by coagulation is as small as 1.0 mm.

Afer an operation has been performed with such a laser device, the levels of the serums GOT, GPT and A1-p are suddenly reduced after the third day and do not recover until as late as one week afterwards.

Further, laser operation devices of this type are of large size and very expensive.

According to the present invention there is provided apparatus for performing surgical operations, the apparatus comprising a monopolar type operating electrode attached to or integral with an end of a coaxial cable and a microwave source connected to the cable such that microwaves can be radiated from the electrode to bio-tissue to enable an operation of coagulation, haemostasis or transection to be performed on the bio-tissue by means of thermal energy generated by the reaction of the microwaves on the bio-tissue.

Apparatus embodying the invention can be used, for example, to perform an operation on a parenchymatous organ having a large blood content, which operation can be performed in an easy, safe and bloodless manner.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a first surgical operation apparatus embodying the present invention;

Figure 2 is a schematic view of a second surgical operation apparatus embodying the present invention;

Figure 3 is a perspective view of main portions of a third surgical operation apparatus embodying the present invention; and

Figure 4 is a sectional view of a manipulating unit of the apparatus of Fig. 3.

Fig. 1 shows a surgical operation apparatus using microwaves that includes a safety device 1 that mainly comprises a reinforced insulating transformer. A power supply 2 is connected to the safety device 1 and includes an automatic voltage stabiliser. A microwave generator device 3 is connected to the power supply 2 and designed to emit microwaves at 2450 MHz with a maximum output of 150 W. A device 4 for selectively limiting the output or emission time is dependence on a disease or condition to be treated is designed to set the microwave output and

radiation time in dependence on the diseased organ, the state of disease, the dimension and condition of the tissue, the part to be operated on, coagulation, haemostasis and transection, etc. Namely, the device 4 is operative to limit and control the output and oscillation time (normally within 60 seconds) of the microwave generator device 3, thereby to prevent an erroneous operation due to excessive radiation, thus enabling operations using microwaves to be performed in a safe and secure manner.

A microwave output fine adjuster device 5 is provided for fine adjustment of the output of the microwave generator device 3. A microwave output impedance matching device 6 is connected to the microwave generator device 3. An operating hand-piece 7 is connected to the impedance matching device 6 by the coaxial cable 8. A monopolar type operating electrode 9 of needle form, having a diameter of 0.5 mm and a length of 3.9 to 31.5 mm, is attached to the hand-piece 7 and thereby to a tip or end of the cable 8. A hand switch 10 attached to the hand-piece 7 is designed to be turned ON when grasped firmly and to be turned OFF when the grasp is relaxed or loosened. A normally closed safety foot switch 11 is connected in series with the hand switch 10 and the primary side of a high voltage transformer in the power supply 2. The foot switch 11 is designed to be turned OFF if pressed by a foot of an operator in case of emergency.

An electrode 13 is connected to a positive terminal of an electrical tissue dissociation source 12 and, in use, comes into contact with tissue adjacent a part or area on which an operation is to be performed. A negative terminal of the source 12 is connected to the operating electrode 9 of the hand-piece 7.

The safety device 1 is operative to prevent high voltage applied to the microwave generator device 3, or high frequency current therefrom, from electrically injuring the operator and the patient undergoing an operation.

The power supply 2 is a rectified power supply for actuating the microwave generator device 3 in a stable manner and can restrain sudden variation of microwave output, caused by variations of an input mains AC power supply to the apparatus, while an operation is being performed.

The apparatus of Fig. 1 is used in the following manner. The operating electrode 9 of the hand-piece 7 is inserted into or brought into contact with the bio-tissue to be operated upon. The hand switch 10 of the hand-piece 7 is turned ON. Microwaves generated by the microwave generator device 3 are then transmitted to the operating electrode through the microwave output impedance matching device 6 and the coaxial cable 8. The microwaves are radiated from the operating electrode 9 to the inside or the surface of the tissue to be operated upon.

At this time, the bio-tissue is dielectrically heated by thermal energy generated by the reaction or effect of the radiated microwaves on the bio-tissue, whereby an operation of transection, coagulation or haemostasis is performed on the tissue.

By turning the hand switch 10 of the hand-piece 7 ON or OFF, the radiation of microwaves is started or stopped, respectively. When the hand switch 10 or the foot switch 11 is turned OFF, the high voltage is shut off to stop the radiation of microwaves.

In actually performing an operation using microwaves, the microwaves output and the microwave application time are selected taking the tissue condition and the vessel sizes, etc. into account, based on the conditions shown in the following table:

Organ	Microwave output (W)	Application time (seconds)
Liver	30–60	30–60
Spleen	30–60	30–60
Ovary	20–50	20–30
Parenchymatous tumour	50	30–60

It is to be noted that the microwave energy is concentrated on the tissue undergoing the operation and therefore exerts no influence upon the tissue at a distance of 15mm or more from the longitudinal axis of the operating electrode 9. Moreover, since the present apparatus does not require a non-active electrode, no microwave current flows into other parts of the patient's body so that no other tissue is injured.

When the operating electrode 9 is pulled out after completion of an operation in which the operating electrode 9 is inserted into the bio-tissue, moisture in the tissue around the operating electrode 9 is evaporated by the dielectric heat of the microwaves and the coagulated tissue disadvantageously tends to stick to the operating electrode 9. To avoid this, after completion of the operation a cathodal direct current (about 10–15 mA) is caused to flow for a very short

period of time (about 5 seconds) from the electrical tissue dissociation source 12 to the operating electrode 9. Moisture is accordingly generated at the interface between the bio-tissue and the operating electrode 9 by electrolysis. Therefore, the tissue coagulated by the dielectric heat of the microwaves does not stick to the operating electrode 9, thereby facilitating dissociation of the operating electrode 9 from the bio-tissue.

A second surgical operating apparatus using microwaves will now be described with reference to Fig. 2. In Fig. 2, a main body 14 of the apparatus incorporates a magnetron 15. A coaxial cable 16 comprises an inner or core conductor or wire 17 and an outer or shield conductor 18. A monopolar type operating electrode 20 of needle form is attached to the tip of an operating hand-piece 19 and thereby to a tip or end of the cable 16. The operating electrode 20 is connected to the output intake loop of the magnetron 15 by the inner conductor 17 of the coaxial cable 16. A metal shield member 21 disposed outside the base portion of the operating electrode 20 is connected to the outer or shield conductor 18 of the coaxial cable 16. The shield conductor 18 is connected to the positive electrode of the magnetron 15 and is earthed in the main body 14.

A coaxial relay device 22 incorporates a relay switch 23, one contact of which is connected to the inner conductor 17 of the coaxial cable 16. An electrical tissue dissociation source 24 has a negative terminal connected to a change-over terminal of the relay switch 23 and a positive terminal connected to the shield conductor 18 of the coaxial cable 16 through the coaxial relay 22. A normally closed foot switch 25 is connected to the main body 14. A relay coil 26 for actuating the relay switch 23 is connected in series with the foot switch 25 and the main body 14. Whilst the foot switch 25 is not being actuated, a high voltage is supplied from a power supply of the main body 14 to the magnetron 15 and the relay coil 26 is excited to connect the relay switch 23 to the open contact.

When the foot switch 25 is pressed by a foot of an operator and is thereby turned OFF, the current supply to the magnetron 15 in the main body 14 is stopped and no current flows to the relay coil 26. The relay switch 23 is then switched and the negative terminal of the electrical tissue dissociation source 24 is connected to the inner conductor 17.

A positive electrode hand-piece 27 has at the tip thereof a positive electrode 28 to which a lead wire 29 is connected. The lead wire 29 is also connected to the positive terminal of the electrical source 24 through the coaxial relay 22. To dissociate the operating electrode 20 from coagulated bio-tissue, the positive electrode 28 is caused to come into contact with the bio-tissue adjacent the part or area at which the operation has been performed.

The bio-tissue, for example the diseased tissue of a parenchymatous organ, is generally designated by the reference numeral 30.

The apparatus of Fig. 2 is used in the following manner. The operating electrode 20 of the hand-piece 19 is inserted into a part of the bio-tissue 30 having a lesion. When the main body 14 is energised, microwaves generated by the magnetron 15 are transmitted to the operating electrode 20 through the inner conductor 17 and radiated to the part having the lesion for 30 to 60 seconds. With the use of dielectric heat produced at this time, haemostasis, coagulation or partial transection is performed on the bio-tissue 30.

After the operation using microwaves has been finished, the foot switch 25 is turned OFF so that the supply of microwaves is stopped and the relay switch 23 of the coaxial relay device 22 is switched over. Then, the negative terminal of the electrical tissue dissociation source 24 is connected to the operating electrode 20 through the inner conductor 17. When the positive electrode 28 of the positive electrode hand-piece 27 is caused to contact the bio-tissue 30, or the metal shield member 21 disposed at the tip of the operating hand-piece 19 is pressed against the bio-tissue 30, a cathodal direct current of about 10mA flows from the electrical source 24 to the operating electrode 20 for a very short period of time (about 5 seconds). Moisture is then produced at the interface between the operating electrode 20 and the bio-tissue 30 by electrolysis, thereby to facilitate dissociation of the operating electrode 20 from the bio-tissue 30. Depending on the condition of the bio-tissue 30, the part operated upon, the operation method and other relevant factors, the surgeon may judge suitably how such dissociation is to be performed, either by contact of the positive electrode 28 with the bio-tissue 30 or by contact of the metal shield member 21 with the bio-tissue 30.

A third surgical operation apparatus using microwaves will now be described with reference to Figs. 3 and 4. With the third apparatus, operations can be performed on organs *in vivo* with the use of a medical endoscope. Thus, with the use of a medical endoscope 31 of conventionally known type, the inside of *in vivo* organs, in particular the stomach, can be directly observed from the outside of the living body, so that clinical diagnosis can be made in a very easy and secure manner.

The medical endoscope 31 has a manipulating portion 32 and a detector portion 34 which is made integral with the manipulating portion 32 by a portion 33 to be inserted *in vivo*. The detector portion 34 is provided in an end surface thereof with a projection light guide hole, an observation image guide hole, an air and water feed hole, a forceps hole, and others.

The manipulating portion 32 has angle knobs 35 and 36 for adjusting the detector portion 34 vertically and horizontally.

The medical endoscope 31 has a light guide 37 and an eye contact portion 38. A forceps channel 39 communicates with the forceps hole in the detector portion 34. Slender forceps, for example, may be inserted into the forceps channel 39 and the tip of the forceps will project from the forceps hole such that an organ and tissue *in vivo* can be held or pressed by external manipulation.

A manipulating unit 40 for operations using microwaves has a hand grip 41. A cylindrical holding member 42 passes through a head of the hand grip 41. A member 43 is slidably fitted to one end of the cylindrical holding member 42. A finger holding portion 44 in a substantially hand drum shape is disposed at the tip of the slidable member 43 in a unitary construction therewith. The slidable member 43 may be slid by operating the finger holding portion 44 with a finger of a hand gripping the hand grip 41.

A reset coil spring 45 is disposed outside the slidable member 43 between the hand grip 41 and the finger holding portion 44. An engagement groove 46 is formed in the outer circumference of the slidable member 43 at the base end thereof.

A pin 47 is inserted into the head of the hand grip 41 and has a tip which engages with the engagement groove 46 in the slidable member 43, thereby to prevent the coils spring 45 from coming out from the slidable member 43.

A coaxial cable 48 for transmitting microwaves extends from the manipulating unit 40 and comprises a central conductor 49, an inner insulating member 50, an outer conductor 51 and an outer shield 52, the members 49, 50, 51 and 52 being coaxially disposed. Respective base ends of the central conductor 49, the inner insulating member 50 and the outer conductor 51 of the coaxial cable 48 are introduced into the cylindrical holding member 42 after passing through the finger holding portion 44 and the slidable member 43. The end of the outer conductor 51 engages with the end surface of the base portion of the slidable member 43. The central conductor 49 is slidable with respect to the inner insulating member 50. The tip or end portion of the coaxial cable 48 is inserted into the forceps channel 39 of the medical endoscope 31 and projects from the forceps hole of the detector unit 34 through the insertion portion 33.

A monopolar type operating electrode 53 designed to be projected and housed is constructed integrally with a central conductor 49 of the coaxial cable 48 projecting from the forceps hole.

A manipulation-end coaxial connector 54 is fitted to the other end of the holding member 42 of the hand grip 41 and is provided at the centre of the inside thereof with a central connection electrode 55 which is held by a holding member 56. The central electrode 55 is connected to the central conductor 49 of the coaxial cable 48 in a straight line form.

A coaxial cable 57 for transmitting microwaves is connected to other parts (not shown) of the microwave operation apparatus, such other parts including a power supply and a microwave generator device. A current-supply-end coaxial connector 58 is disposed at the tip of the coaxial cable 57 and connected to the manipulation-end coaxial connector 54. The coaxial connector 58 incorporates an electrode to be connected to and disconnected from the central electrode 55 of the manipulation-end coaxial connector 54.

The apparatus of Figs. 3 and 4 is used in the following manner. The detector portion 34 and the insertion portion 33 of the medical endoscope 31 are inserted *in vivo*. With the aid of the angle knobs 35 and 36 of the manipulating portion 32, the detector portion 34 is guided to a part of an *in vivo* organ having a lesion, for example in the stomach. With the hand grip 41 grasped in one hand, the finger holding portion 44 is pulled, with a finger of such hand, towards the operator against the action of the coil spring 45. The finger holding portion 44 and the slidable member 43 are thus slid into the cylindrical holding member 42. The outer conductor 51 of the coaxial cable 48, of which the end is engaged with the slidable member 43, is moved towards the operator, i.e. towards the central electrode 55, in accordance with the movement of the slidable member 43. The inner insulating member 50 of the coaxial cable 48 is integral with the outer conductor 51, and the inner conductor 49 is slidable with respect to the inner insulating member 50. Therefore, in accordance with the movement of the outer conductor 51, the inner insulating member 50 is slid towards the central conductor 49, and the operating electrode 53, integral with the central conductor 49, is projected from the tip of the detector portion 34 of the endoscope 31. The thus-projected operating electrode 53 is contacted with or inserted into the diseased tissue. When the microwave operation apparatus is then energised, microwaves generated by the microwave generator device are transmitted to the operating electrode 53 throught the coaxial cables 57 and 48.

The microwaves are radiated from the operating electrodes 53 to the diseased tissue. Thus, an operation of haemostasis or coagulation can be performed on the diseased tissue with the use of thermal energy generated by the reaction or effect of the microwaves on the bio-tissue. After the operation has been completed, the pull on the finger holding portion 44 of the manipulating unit 40 is released. By virtue of the action of the coil spring 45, the slidable member 43 is then slid together with the finger holding portion 44 in the direction opposite to

that mentioned above. Thus, the operating electrode 53 at the tip of the medical endoscope 31 is retracted and housed. It is to be noted that such procedures can all be performed under direct observation by the operator or surgeon through the eye contact portion 38 of the manipulaing portion 32.

The surgical operation methods and apparatus described above may be used to preform coagulation, haemostasis or transection operations on bio-tissue with the use of thermal energy generated by the reaction or effect of microwaves on the bio-tissue. The bio-tissue may be operated upon in an easy, safe and bloodless manner. Therefore, the methods and apparatus described above can be utilised for operation on parenchymatous organs having a large blood content, such as the brain, lungs, liver, spleen, kidney or ovaries, and also for coagulation or transection (partial transection) of parenchymatous tumours. Therefore, when haemostasis or partial transection is made by a method or apparatus as described above, the spleen can be preserved. Thus, it can be expected that the present methods and apparatus will be widely applicable to operations that have heretofore been generally regarded as very difficult.

Apparatus embodying the present invention preferably uses a power supply, for example, having a frequency of 2450 MHz, a wavelength of 12 cm and an output of 30–100 W, and does not require a non-active electrode—as is the case in an electrocautery—so that the apparatus can be economically manufactured in a small size and its manipulation is very easy.

Advantages that may be obtained by means of the surgical operation methods and apparatus using microwave in accordance with the foregoing disclosure will be discussed in the following.

The maximal diameter of vessels which can possibly be subjected to haemostasis can be increased to as much as 3 mm for the artery and the vein, and the maximal diameter of the introhepatic bile duct which can possible be closed by coagulation can also be increased to as much as 3 mm. At the liver stump, neither secondary haemorrhage after operation nor cholerrhagia after operation is observed.

The remanent period of the coagulation necrosis tissue is as long as 3 to 6 months, so that haemostasis can be safely performed.

By virtue of the microwave heat generated in the bio-tissue, many kinds of bacteria are sterilised and no blood stream is present, so that no infection takes place.

The decrement rate of stretch moment of the coagulated vessels is 18.6% for the artery and 17.5% for the vein. The regeneration rate of remnant liver cell (the weight of liver) is 140% on the 21st day after an operation of 30% partial transection on the liver.

As to the general effects on body condition, the body temperature does not rise and no irreversible change followed by the breaking of tissue is observed. The conditions of the serums GOT, GPT and A1-p recover 24 hours after the operation. There is no risk of hepatopathy occurring thereafter.

Observation 6 months after the operation does not show any complicating diseases and general effects on the body condition peculiar to the present methods.

After the completion of an operation using microwaves according to the techniques described above, a cathodal current is supplied to the operating electrode inserted in the bio-tissue, thus enabling the operating electrode to be dissociated. Therefore, no coagulated tissue sticks to the operating electrode at the time of dissociation, thus eliminating the necessity of pulling the operating electrode out with the use of some such instrument as a TZUPEL. Accordingly, the operations can be performed more smoothly.

When the present technique is applied with a medical endoscope, an operating electrode attached to the tip of a coaxial cable is projected from the tip of the insertion portion of the medical endoscope. Therefore, diseased tissue in the organ *in vivo* can be operated upon with the use of microwaves outside the living body.

Furthermore, since the operation can be performed under direct observation, the operation can be safely and accurately conducted on, for example, a gastric ulcer or gastric cancer.

CLAIMS

1. Apparatus for performing surgical operations, the apparatus comprising a monopolar type operating electrode attached to or integral with an end of a coaxial cable and a microwave source connected to the cable such that microwaves can be radiated from the electrode to bio-tissue to enable an operation of coagulation, haemostasis or transection to be performed on the bio-tissue by means of thermal energy generated by the reaction of the microwaves on the bio-tissue.

2. Apparatus according to claim 1, comprising means for supplying a cathodal current to the operating electrode inserted in the bio-tissue after an operation has been finished, thereby to generate moisture by electrolysis at the interface between the operating electrode and the bio-tissue, thus enabling the operating electrode to be dissociated from the bio-tissue.

3. Apparatus according to claim 1 or claim 2, wherein the coaxial cable is capable of being inserted into a medical endoscope and the operating electrode is capable of being projected from the tip of a portion of the endoscope to be inserted *in vivo*, whereby an operation using

microwaves can be performed on an *in vivo* organ under direction observation.

4. Apparatus for performing surgical operations, the apparatus being substantially as herein described with reference to Fig. 1, Fig. 2 or Figs. 3 and 4 of the accompanying drawings.

5. A surgical operation method comprising radiating microwaves to bio-tissue from a monopolar operating electrode attached to or integral with an end of a coaxial cable for transmitting microwaves, and performing an operation of coagulation, haemostasis or transection on the bio-tissue by means of thermal energy generated by the reaction of the microwaves on the bio-tissue.

6. A method according to claim 5, whrein a cathodal current is supplied to the operating electrode, inserted in the bio-tissue after an operation has been finished, thereby generating moisture by electrolysis at the interface between the operating electrode and the bio-tissue thus enabling the operating electrode to be dissociated from the bio-tissue.

7. A method according to claim 5 or claim 6, wherein said coaxial cable is inserted into a medical endoscope and the operating electrode is projected from the tip of a portion of the endoscope to be inserted *in vivo*, whereby an operation using microwaves is performed on an *in vivo* organ under direct observation.

8. A surgical operation method substantially as herein described with reference to Fig. 1, Fig. 2 or Figs. 3 and 4 of the accompanying drawings.

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